S8-47
197508
p. 4

N94-22300

Cloud Properties from the Analysis of AVHRR Observations for FIRE II

Xijian Lin and James A. Coakley, Jr.

College of Oceanic and Atmospheric Sciences
Oregon State University
Corvallis, OR 97331–2209

1. Introduction

Preliminary results are presented for cloud properties from the analysis of AVHRR observations for FIRE II. The properties were obtained from a combination of the spatial coherence method (Coakley and Bretherton, 1982) and a multispectral retrieval scheme (Lin and Coakley, 1993). Geographically gridded fields for the number of cloud layers were produced. For single-layered cloud systems, fractional cloud cover, cloud emission temperature, cloud emissivity and particle size were retrieved. Statistics on the properties of upper-level clouds and the Coffeeville cloud conditions are presented.

2. Method

The processing of AVHRR data obtained during FIRE II involved two steps. The first step used the spatial coherence method to distinguish between single and multilayered cloud systems and to obtain cloud-free radiances. Each satellite overpass was divided into subframes which, in this study, were arrays of 32 by 32 4–km pixels and were equivalent to ~ 100–km scale regions. Cloud layer structure and cloud-free radiances were obtained for each subframe. The second step used a multispectral retrieval scheme to obtain cloud properties for those systems found to be single-layered within the ~ 100–km scale subframes.

The multispectral retrieval scheme used an automated procedure for fitting two-wavelength radiance pairs obtained from radiative transfer calculations to those observed by satellite. In the radiative transfer calculations, the cloud was assumed to be single-layered and homogeneous in emission temperature and particle size throughout the 100–km scale region. The cloud particles were assumed to be ice spheres at one effective radius. Radiances observed in IR windows were taken to be given by:

$$I_i = (1 - A_c)I_{si} + A_c(e_i I_{ci} + t_i I_{si}) \tag{1}$$

where the subscript i represents the instrument channel number; A_c is the fractional cloud cover within the field of view (FOV); I_{si} is the cloud-free radiance; I_{ci} is taken to be given by the Planck function at the cloud emitting temperature; e_i and t_i are the mean emissivity and transmissivity for the cloud. Mie theory was used to calculate the single particle extinction efficiency, single

scattering albedo and asymmetry given the effective radius, R_{eff}. The Eddington approximation was used to calculate the cloud emissivity and transmissivity given the ice water path length.

Lin and Coakley (1993) describe the method of fitting (1) to observed satellite radiances. Figure 1 shows 11 and 12–μm radiance pairs calculated on the basis of (1). Figure 2 shows a typical fit to observations obtained during FIRE II. The observations are for a $\sim$ 100–km scale subframe. Each point in the figure gives radiances for a 4–km pixel. In this case the cloud emission temperature was 240°K and the effective radius was 4.0 μm. Based on the best fit, pixel-scale cloud emissivity and fractional cloud cover are obtained from the pixel's position in the radiance domain as given by the radiative transfer calculations. The 100–km scale cloud emissivity and fractional cloud cover are obtained by averaging the pixel-scale results.

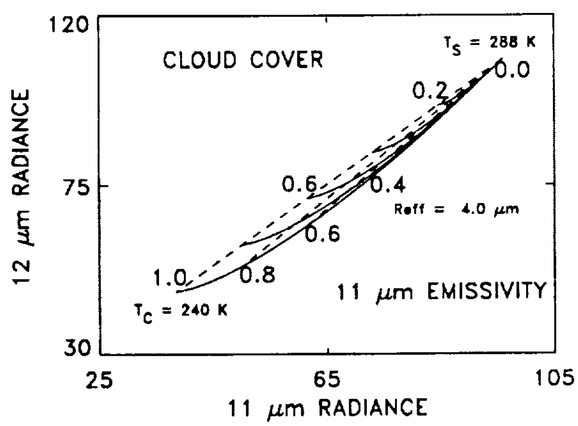

Figure 1 Theoretical relationships for 11 and–12 μm radiances (mW$m^{-2}sr^{-1}$cm) for single layered cloud system.

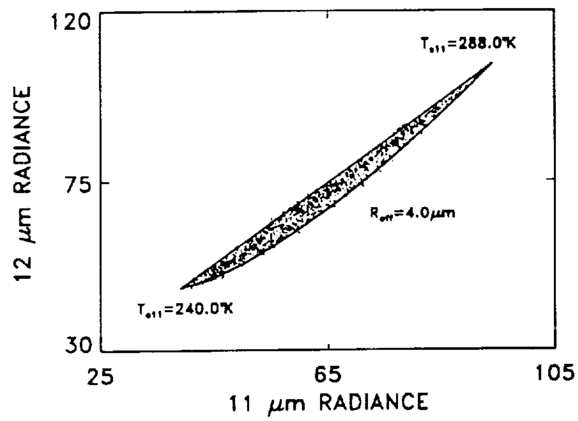

Figure 2 Fit of model results in Fig. 1 to satellite radiances obtained during FIRE II

3. Results

Based on the method described above, NOAA-11 daytime data have been processed. 44 overpasses were processed spanning November 13 — December 7. Statistics on the cloud systems obtained from the 44 overpasses are displayed in Figure 3. The Y-axis is the number of subframes. On the X-axis, CLR represents cloud—free subframes (100–km scale region); SGL: single-layered cloud system for which cloud properties were retrieved; XXX: single-layered cloud system for which properties were not retrieved because the clouds were either opaque or contained large particles; MLT: multi-layered cloud system, no retrievals; YYY: analysis failed for six overpasses because of missing scan lines and missing pixels, or other technique problems. It seems that cloud-free, single-layered and multi-layered cloud systems were equally common on the 100–km scale.

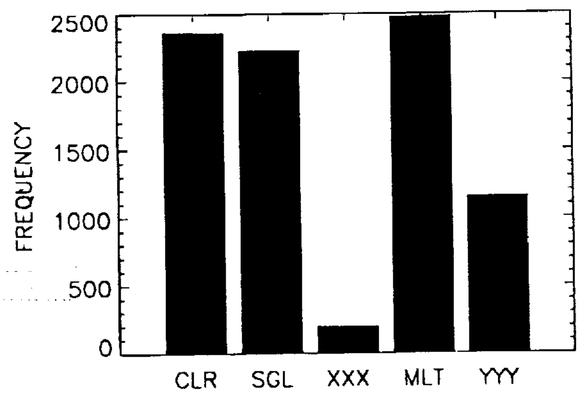

Figure 3 Cloud layer statistics.

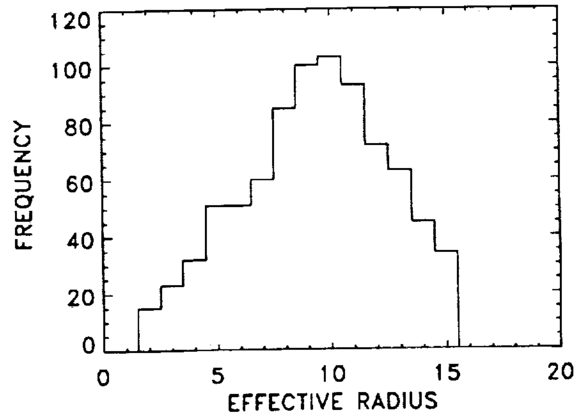

Figure 4 Upper-level cloud particle sizes. The X-axis is the effective radius and the Y-axis is the number of subframes.

Clouds with emission temperatures < 245°K were taken to be upper-level clouds, presumably cirrus. Figure 4 displays the distribution of retrieved particle sizes for upper-level clouds. Because of the simple radiative transfer model, the effective radius should be interpreted only as a size index. In addition, there were no retrievals for opaque clouds and for clouds with particles larger than 15 μm because there is no way to distinguish between opaque clouds and clouds having large particles on the basis of emission at 11 and 12 μm. Fortunately, only a small fraction of the subframes showed this ambiguity, as indicated in Fig. 3 by the results for XXX. In addition, for the upper-level single layered clouds the 100–km average 11–μm emissivities were found to be positively correlated with the regional scale cloud cover.

Satellite observed cloud properties over Coffeeville, Kansas were obtained for comparison with *in-situ* observations during the FIRE II experiment. Table 2 gives the cloud conditions over Coffeeville, Kansas. The results were obtained for the $\sim$ 100—km subframe which was nearest Coffeeville for each NOAA-11 overpass and for which the center longitude and latitude deviated from Coffeeville's by less than 2 degrees. In the table, ST is the start time of the overpass (HHMMSS, GMT); (X,Y): subframe center latitude, west longitude;Tc: cloud emission temperature if single-layered semitransparent clouds were observed.

4. Future Work

Based on the preliminary results, the following is under consideration for future work:

1. Process all of the AVHRR data obtained during the FIRE II experiment.
2. Obtain lidar and radar observations to compare retrieved cloud heights and to verify the retrieved results.
3. Carry on retrievals simultaneously using different combinations of 3.7–12 μm and 0.63–12 μm
4. Improve the radiative transfer model used in the retrieval.

Table 1 Cloud conditions over Coffeeville on indicated days in November and December.

10 /	11 /	12 /	13 / SGL ST=200300 (36.9, 95.2) Tc=233.1	14 / MLT ST=195200 (37.1, 95.0)	15 / SGL ST=212800 (36.4, 96.8) Tc=253.7	16 / SGL ST=211600 (36.3, 97.2) Tc=243.8
17 / CLR ST=210500 (36.3, 96.8)	18 / CLR ST=205200 (36.6, 96.0)	19 / MLT ST=203500 (36.8, 96.1)	20 / NO-data	21 / CLR ST=201000 (36.8, 95.2)	22 / MLT ST=195800 (36.7, 96.3)	23 / No-data
24 / SGL ST=212400 (36.9, 96.0) Tc=255.2	25 / SGL ST=211200 (36.7, 95.8) Tc=258.4	26 / SGL ST=210000 (36.5, 95.5) Tc=214.3	27 / No-data	28 / No-data	29 / No-data	30 / No-data
1 / No-data	2 / SGL ST=213000 (36.8, 97.4) Tc=238.7	3 / MLT ST=211800 (36.9, 94.4)	4 / CLR ST=210600 (36.7, 94.6)	5 / MLT ST=205500 (36.8, 96.0)	6 / CLR ST=203700 (37.0, 96.1)	7 / CLR ST=202400 (36.2, 96.0)

5. Acknowledgment

We thank Fu-lung Chang and Guy Boulanger for their help in data processing. This work was supported by NASA Grant NAG-1-1234.

6. References

Coakley, J.A., Jr. and F.P. Bretherton, 1982: "Cloud cover from high-resolution scanner data: Detecting and allowing for partially filled fields of view", *J. Geophys. Res.*, **87**, 4917–4932, 1982.

Lin, X. and J.A. Coakley, Jr., 1993: "Retrieval of properties for semitransparent clouds from multispectral infrared imagery data", *J. Geophys. Res.* (in press).